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Patterns of youth tobacco and polytobacco usage: The shift to alternative tobacco products

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ABSTRACT

Background: Despite significant declines in youth cigarette smoking, overall tobacco usage remains over 20% as non-cigarette tobacco product usage is increasingly common and polytobacco use (using 1+ tobacco product) remains steady. **Objectives:** The present study was designed to identify patterns of youth tobacco use and examine associations with sociodemographic characteristics and tobacco dependence. **Methods:** The current analysis uses Latent Class Analysis (LCA) to examine the 6,958 tobacco users ($n = 2,738$ female) in the National Youth Tobacco Survey (2012 and 2013). We used as indicators past month use of tobacco products (cigarettes, cigars, smokeless tobacco, e-cigarettes, hookah, snus, pipes, bidis, and kreteks) and regressed resulting classes on sociodemographic characteristics and tobacco dependence. **Results:** Nine classes emerged: cigarette smokers (33.4% of sample, also included small probabilities for use of cigars and e-cigarettes), cigar smokers (16.8%, nearly exclusive), smokeless tobacco users (12.3%, also included small probabilities for cigarettes, cigars, snus), hookah smokers (11.8%), tobacco smokers/chewers (10.7%, variety of primarily traditional tobacco products), tobacco/hookah smokers (7.2%), tobacco/snus/e-cig users (3.3%), e-cigarette users (2.9%), and polytobacco users (1.7%, high probabilities for all products). Compared to cigarette smokers, tobacco/hookah smokers and hookah smokers were more likely to report Hispanic ethnicity. Polytobacco users were more likely to report dependence (AOR:2.77, 95% CI:[1.49–5.18]), whereas e-cigarette users were less likely (AOR:0.49, 95% CI:[0.24–0.97]). **Conclusion:** Findings are consistent with other research demonstrating shifts in adolescent tobacco product usage towards non-cigarette tobacco products. Continuous monitoring of these patterns is needed to help predict if this shift will ultimately result in improved public health.

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1. Introduction

Cigarette smoking remains the leading preventable cause of death in the United States, with estimates suggesting that over 5 million youth, or two out of every 27 children alive in the United States today, will die prematurely from cigarette smoking (1). Tobacco use is established primarily during adolescence, with 9 out of 10 of those with a history of daily cigarette smoking first trying smoking by age 18, and 99% first trying by age 26 (1,2). From 2011 to 2014, despite cigarette smoking among high-school students declining significantly from 16% to 9%, overall high-school tobacco use remained steadily above 20% (3). Youth use of little cigars (4), hookah (5,6), and electronic nicotine delivery systems (“e-cigarettes”) (7) filled in the gap (3). At present, despite ample evidence that cigarette smoking is linked to premature death, the health risks related to other forms of tobacco use are much more controversial (8–10).

Rates of use of more than one tobacco product, i.e., polytobacco use, have remained stable and relatively high in the United States among both young adults (11) and high-school students (3), with some product combinations, such as cigarettes and smokeless tobacco, increasing in frequency (11,12). In 2012, more than twice as many youth used two or more tobacco products than cigarettes alone (12). In 2014, an estimated 2.2 million middle- and high-school students reported current use of 2 or more tobacco products (3). Our understanding of the relationships between use of various tobacco products is profoundly limited, especially given concerns that alternative tobacco products can act as a “gateway” or “catalyst” towards cigarette smoking (13–15).

Latent Class Analysis (LCA) is a form of latent modeling that groups individuals based on patterns of questionnaire responses (“indicators”) (16–18). LCA assumes that “latent”, i.e., unobserved, classes can be

derived that explain any association between reported indicators. This assumption implies that classes can be interpreted as homogenous and distinct, so that within any class the item reporting patterns differ only by random error. The derived latent classes consist of probabilities of indicator endorsement. LCA has been used increasingly in drug dependence epidemiology (19–23), and with polytobacco usage specifically based on the 2009 wave of the National Youth Tobacco Survey (NYTS) (24) and the 2010–2011 follow-up wave of the Minnesota Adolescent Community Cohort (MACC) (25). Although useful, these prior analyses require updating, given the rapid changes in the tobacco landscape. For example, the 2009 NYTS did not include questions on hookah or e-cigarette usage, while the 2010–2011 MACC analysis only examined lifetime usage of tobacco products, as their sample included relatively low rates of past-month hookah or e-cigarette usage. Examining a more contemporary, nationally representative survey is needed to better understand patterns of youth tobacco use, particularly in relation to more prevalent e-cigarette and hookah usage. Additionally, it is important to examine these groups in relation to age, gender, and race to better understand contemporary usage patterns and long-term addiction risk. Thus, the present study aims to use LCA to identify classes of youth tobacco users and relate identified classes to sociodemographic and nicotine dependence variables.

2. Methods

2.1. Study sample and data collection

We constructed our dataset from the 2012 and 2013 waves of the National Youth Tobacco Survey (NYTS). The NYTS is a complex survey using a stratified, three-stage cluster design to produce a representative sample of all middle- and high-school students in the 50 US states and DC. The survey includes students enrolled in a middle- or high-school regardless of their age. Non-Hispanic Black and Hispanic students were oversampled (26,27). For the present analysis, we used unweighted estimates. The protocols were approved by Center for Disease Control and Prevention Institutional Review Board-G (26–28). The 2012 NYTS ($N = 24,658$) had a school participation rate of 80.3% and a student participation rate of 91.7%, for an overall rate of 73.6% (26). The 2013 NYTS ($N = 18,406$) had a school participation rate of 74.8% and a student participation rate of 90.7%, yielding an overall rate of 67.8% (27). We limited our analyses to 2012 and 2013 as they were the most

recent datasets publicly available at the time of analysis that assessed a tobacco dependence variable (how soon upon waking respondents reported tobacco craving). We restricted our analyses to respondents who were past-30-day tobacco users and indicated use of at least one of the nine tobacco products described below, yielding 6,841 respondents.

2.2. Latent class indicators

Classes were based on past-30-day use of the nine tobacco products outlined in Table 1. These included cigarettes, cigars, smokeless tobacco, pipe, bidis, kreteks, hookah, snus, and e-cigarettes. The cigar product category explicitly included cigarillos and little cigars. Smokeless tobacco was defined as chewing tobacco, snuff, or dip. Pipe was explicitly defined as not from a waterpipe, while the hookah category was described as hookah or waterpipe. Snus was described as including Camel or Marlboro. The e-cigarette description included electronic cigarettes, such as Ruyan or NJOY.

2.3. Statistical analyses

The tobacco product items were coded as binary indicators of a latent categorical variable in a LCA using SAS SUDAAN. As this analysis involves some tobacco products with fairly low usage that have been left out of some prior studies, it was expected that the models might include “boundary values”, i.e., probability estimates of zero or one. Although these values are not necessarily unexpected, they result in estimates for which it is impossible to calculate a standard error. Thus, a rho (ρ)-stabilizing prior strength of 1 was used to improve estimation and reduce the likelihood of boundary values (29). This statement replaced the STABILIZE command from prior versions of SAS PROC LCA and acts similarly to the “Bayes constant” for “categorical variables” in the latent class clustering functionality in LatentGOLD (30).

Starting with one class and incrementally increasing the number of classes, a series of LCA models were fit to the data. We used Bayesian Information Criteria (BIC) and sample size adjusted BIC (aBIC) as indicators of the optimal number of classes for the latent categorical variable (18). Each class threshold was run multiple times to ensure that we generated a global, rather than local, maximum likelihood of the latent class model. The utility and precision of the resulting classes was assessed using entropy (31,32). Entropy ranges from 0 to 1 with higher values indicating better class separation. After the optimal number of classes for

Table 1. Sample characteristics of 6841 past month tobacco product users.¹

	<i>n</i>	%
Demographics		
Gender		
Male	4088	59.9%
Female	2738	40.1%
Age		
9–13 years old	829	12.2%
14–18 years old	5797	85.6%
19+ years old	150	2.2%
Race/ethnicity		
White, Non-Hispanic	3167	47.7%
Hispanic	1730	26.1%
Black, Non-Hispanic	953	14.3%
Asian, Non-Hispanic	136	2.0%
Other, Non-Hispanic	653	9.8%
Tobacco Product Usage²		
Cigarettes		
Use in past 30 days	3785	58.2%
No use in past 30 days	2721	41.8%
Cigars (including cigarillos and little cigars)		
Use in past 30 days	3497	52.6%
No use in past 30 days	3153	47.4%
Smokeless tobacco		
Use in past 30 days	1717	25.8%
No use in past 30 days	4930	74.2%
Pipe (non-hookah)		
Use in past 30 days	1388	20.9%
No use in past 30 days	5268	79.1%
Bidis		
Use in past 30 days	301	4.7%
No use in past 30 days	6082	95.3%
Kreteks (AKA cloves)		
Use in past 30 days	302	4.7%
No use in past 30 days	6081	95.3%
Hookah (AKA waterpipe, shisha, narghile)		
Use in past 30 days	1441	22.6%
No use in past 30 days	4942	77.4%
Snus		
Use in past 30 days	639	10.0%
No use in past 30 days	5744	90.0%
E-cigarettes		
Use in past 30 days	1026	16.1%
No use in past 30 days	5357	83.9%
Dependence Measure		
First tobacco craving upon waking		
Do not use tobacco or rarely want to use tobacco	3989	60.6%
After more than 1 hour but less than 24 hours	876	13.3%
From more than 30 minutes to 1 hour	457	6.9%
From 6 to 30 minutes	577	8.8%
Within 5 minutes	681	10.3%

¹ Sub-categories do not always add up to total sample size due to missing data.

² Tobacco product usage variables were used as latent class indicators.

the latent categorical variables were determined, we used the resulting probabilities to assign individuals to classes based on Most Likely Class Membership for analysis in a regression model. This approach is appropriate given adequate entropy. We refer to probabilities ranging from 0.50–1.00 as high, while probabilities ranging from 0.10 to 0.49 are referred to as moderate. The dependent variables in the multinomial logistic regression model included the following four covariates: (1) race/ethnicity, coded as Non-Hispanic White, Non-Hispanic Black, Hispanic ethnicity, Non-Hispanic Asian, and Non-Hispanic Other; (2) sex; (3) age bracket, coded as 9 to 13, 14 to 18, and 19 or older; and (4) how soon after waking each respondent wanted

to use tobacco, used as a proxy for nicotine dependence (33), coded as <5 minutes, from 6 to 30 minutes, from 30 minutes to an hour, from 1 hour to less than 24 hours, and rarely or never wanting to use tobacco.

3. Results

3.1. Fit statistics

Based on both BIC and aBIC, we chose a 9-class model. BIC decreased for each subsequent model from 1-class to 8-classes, but the BIC for the 8, 9, and 10 class models were 1542.33, 1525.20, and 1597.95, respectively. The aBIC similarly showed a change in direction following the 9-class model with values of 1291.29, 1242.38, and 1283.35 for the 8 to 10 class models. Entropy for the 9-class model is 0.78. Potential upper limit boundary values were found for cigarette smoking among class 1 and for cigar smoking among class 2 (34). One potential lower limit boundary value was found for snus among class 2. All other probability estimates included standard errors between 0 and 1.

3.2. Class descriptions

Table 2 shows estimated probabilities for past-month tobacco use for each latent class. The first class delineated in the model, comprising almost a third of the sample of youth tobacco users, consisted of an extremely high probability for cigarette smoking (1.00) and moderate probabilities for cigar smoking (0.36) and e-cigarette use (0.14), but near-zero probabilities for all other forms of tobacco use (all < 0.07). They are thus referred to as “Cigarette Smokers.” The second class, consisting of 16.8% of the sample, demonstrated high probabilities for smoking cigars (including little cigars and cigarillos), but near zero probabilities for all other types of tobacco use and thus is referred to as “Cigar Smokers.” The third largest class, consisting of 12.3% of the sample, involved a high probability for smokeless tobacco use and moderate (0.19–0.27) probabilities for cigar smoking, cigarette smoking, and snus use, but near-zero probabilities for all other types of tobacco use, leading to a class title of “Smokeless Tobacco Users.”

As shown in Table 2, more than one-ninth of all young tobacco users were categorized in the fourth class, which included a fairly high probability for hookah smoking, as well as moderate probabilities for pipe and cigar smoking. This class is referred to as “Hookah Smokers.” The fifth class includes high probabilities for cigarette and cigar smoking, as well as smokeless tobacco and pipe use, with moderate probabilities for all other tobacco products (range

Table 2. Probabilities and standard errors of past-month tobacco product usage by latent class of 6841 youth tobacco users.

Tobacco products	LC1	LC2	LC3	LC4	LC5	LC6	LC7	LC8	LC9
	(n = 2287, 33.4%) Cigarette Smokers	(n = 1149, 16.8%) Cigar Smokers	(n = 843, 12.3%) Smokeless Tobacco Users	(n = 804, 11.8%) Hookah Smokers	(n = 729, 10.7%) Tobacco Smoke/ Chewers	(n = 493, 7.2%) Tobacco/ Hookah Smokers	(n = 223, 3.3%) Tobacco/ Snus/E-cig Users	(n = 200, 2.9%) E-cigarette Users	(n = 113, 1.7%) Polytobacco
Cigarettes	1.00 (0.00)	0.02 (0.07)	<i>0.27 (0.07)</i>	0.01 (0.01)	0.87 (0.03)	0.84 (0.13)	0.83 (0.09)	0.01 (0.03)	0.94 (0.02)
Cigars	<i>0.36 (0.04)</i>	1.00 (0.00)	<i>0.19 (0.03)</i>	<i>0.29 (0.08)</i>	0.89 (0.04)	0.65 (0.07)	0.59 (0.12)	<i>0.22 (0.04)</i>	0.91 (0.00)
Smokeless Tobacco	0.03 (0.04)	0.00 (0.00)	0.96 (0.01)	0.07 (0.02)	0.75 (0.11)	0.00 (0.00)	1.00 (0.00)	0.00 (0.11)	0.86 (0.05)
Hookah	0.06 (0.03)	0.02 (0.04)	0.00 (0.00)	0.74 (0.04)	<i>0.27 (0.05)</i>	0.63 (0.20)	<i>0.28 (0.09)</i>	0.05 (0.05)	1.00 (0.00)
Pipe	0.05 (0.03)	0.06 (0.01)	0.00 (0.01)	<i>0.36 (0.03)</i>	0.69 (0.06)	<i>0.49 (0.09)</i>	0.20 (0.24)	0.02 (0.06)	0.92 (0.03)
Snus	0.04 (0.01)	0.00 (0.00)	<i>0.22 (0.02)</i>	0.00 (0.00)	<i>0.18 (0.06)</i>	0.04 (0.03)	0.55 (0.16)	0.00 (0.06)	0.97 (0.03)
E-cigarettes	<i>0.14 (0.01)</i>	0.00 (0.00)	0.01 (0.01)	0.03 (0.04)	<i>0.16 (0.07)</i>	<i>0.36 (0.10)</i>	<i>0.48 (0.10)</i>	1.00 (0.07)	0.92 (0.04)
Bidis	0.01 (0.00)	0.01 (0.00)	0.00 (0.00)	0.05 (0.01)	<i>0.13 (0.03)</i>	0.06 (0.03)	0.01 (0.02)	0.01 (0.03)	0.95 (0.03)
Kreteks	0.01 (0.01)	0.02 (0.01)	0.01 (0.00)	0.02 (0.01)	<i>0.14 (0.03)</i>	0.07 (0.03)	0.02 (0.02)	0.04 (0.03)	0.90 (0.04)

Note: Probabilities greater than 0.49 are shown in bold. Probabilities ranging from 0.10-0.49 are shown in italics.

between 0.13 for bidis to 0.27 for hookah). This class is referred to as “Tobacco Smokers/Chewers.” The sixth class, comprised of 7.2% of the sample, includes a high probability of cigarette, cigar, and hookah smoking and moderate probabilities for pipe and e-cigarette use. As the class with the second highest probability of hookah use, this class is referred to as “Tobacco/Hookah Smokers.”

Class 7 consisted of individuals with high probabilities for cigarettes, smokeless tobacco, cigars, and snus, as well as moderate probabilities for e-cigarettes, hookah, and pipe usage. Given that this class includes the highest probability of snus use of all the 9 classes, as well as a relatively high probability of e-cigarette usage, we refer to this class as “Tobacco/Snus/E-cig Users.” The next class, accounting for 2.9% of all youth tobacco users in 2012 and 2013, consisted of a very high probability of e-cigarette use (0.999), a moderate probability of cigar smoking (0.22), and near-zero probabilities for all other forms of tobacco use; we thus refer to this class as “E-cigarette Users.” We considered using the term “Vapers”, a common colloquial term for e-cigarette users, but there are concerns this term increases the risk of the misperception that e-cigarettes emit a harmless water vapor, rather than a complex aerosol mix of questionable health consequence. The final class, consisting of less than 2% of the total sample, included very high probabilities for all tobacco products examined. We thus refer to this class as “Polytobacco Users.”

3.3. Class relationships with sociodemographics and dependence

As the largest class and the most similar to historical norms, Cigarette Smokers are used as the reference class. As shown in Table 3, compared to children under 13 years old, those 14–18 years old were more likely to be

Tobacco/Hookah Smokers. In regards to race/ethnicity, African-Americans were 1.6 times more likely than Whites to be Cigar Smokers, but less likely to be Smokeless Tobacco Users. Hispanics were more likely than Whites to be both Hookah Smokers and Tobacco/Hookah Smokers. Those identifying their race as Other were more likely to be Polytobacco Users. Regarding the measure of dependence, E-cigarette Users were less likely than Cigarette Smokers to report any craving for a tobacco product in the first five minutes after waking, as compared to reporting not using tobacco or rarely wanting to use tobacco. Polytobacco Users were more likely to report tobacco craving in the first five minutes after waking.

4. Discussion

Classes demonstrate new forms of tobacco use. Classes relatively dominated by a single substance emerged for cigarettes, cigars, smokeless tobacco usage, and e-cigarettes, while five additional classes (Hookah Smokers, Tobacco Smokers/Chewers, Cigarette/Hookah Smokers, Tobacco/Snus/E-cig users, Polytobacco users) revealed a variety of tobacco product usage patterns. Although still the leading form of youth tobacco use in 2012 and 2013, the latent class “Cigarette Smokers” in the present study accounted for about a third of all tobacco usage and also included some notable probabilities of cigar and e-cigarette usage. This demonstrates a shift in youth tobacco product typologies. This contrasts with, for example, a LCA of the 2009 NYTS, a dataset which did not include information on hookah or e-cigarette use and was instead based on levels of lifetime cigarette smoking, cigarette consumption patterns, and past-month use of smokeless tobacco, cigars, bidis, and kreteks (35). The identified solution included classes of both daily and non-daily smokers that differed drastically in use of non-cigarette tobacco products. At the time,

Table 3. Adjusted odds ratios for class membership for 6841 youth tobacco users.

	LC2 Cigar Smokers ¹ (n = 1149)	LC3 Smokeless Tobacco Users (n = 843)	LC4 Hookah Smokers (n = 804)	LC5 Tobacco Smoke/Chewers (n = 729)	LC6 Tobacco/Smokers (n = 493)	LC7 Tobacco /Snus /E-cig (n = 223)	LC8 E-cigarette Users (n = 200)	LC9 Polytobacco (n = 113)
Age								
9-13	Referent							
14-18	1.07 (0.72-1.60)	1.01 (0.68-1.49)	0.90 (0.61-1.34)	0.93 (0.67-1.30)	1.62 (1.03-2.54)	0.87 (0.54-1.42)	0.98 (0.50-1.89)	1.91 (0.87-4.21)
19-21	0.65 (0.29-1.43)	0.77 (0.33-1.84)	1.45 (0.70-2.99)	1.07 (0.50-2.29)	0.90 (0.35-2.34)	1.53 (0.47-4.94)	1.95 (0.65-5.84)	3.40 (0.57-20.1)
Race/ethnicity								
White, Non-Hispanic	Referent							
Hispanic	1.30 (0.70-2.41)	0.97 (0.48-1.95)	1.41 (0.61-3.27)	0.60 (0.27-1.3)	1.27 (0.55-2.91)	0.50 (0.13-1.92)	0.48 (0.13-1.82)	0.78 (0.14-4.45)
Asian, Non-Hispanic	1.60 (1.24-2.06)	0.67 (0.51-0.95)	1.01 (0.66-1.54)	0.74 (0.54-1.02)	0.96 (0.61-1.52)	0.90 (0.45-1.79)	0.73 (0.40-1.32)	0.80 (0.36-1.76)
Black, Non-Hispanic	1.12 (0.85-1.49)	0.81 (0.60-1.09)	1.54 (1.13-2.11)	1.14 (0.87-1.49)	1.46 (1.07-1.99)	0.91 (0.63-1.31)	0.79 (0.49-1.27)	1.03 (0.56-1.89)
Hispanic	1.24 (0.91-1.69)	1.03 (0.70-1.52)	0.88 (0.61-1.28)	1.07 (0.71-1.59)	1.27 (0.77-2.1)	0.66 (0.36-1.22)	0.72 (0.37-1.40)	2.71 (1.49-4.92)
Other								
Sex								
Male	Referent							
Female	1.05 (0.87-1.26)	0.99 (0.80-1.23)	1.05 (0.51-1.30)	1.04 (0.85-1.28)	0.95 (0.73-1.24)	0.84 (0.58-1.21)	1.08 (0.77-1.50)	1.44 (0.88-2.35)
First tobacco craving ²								
Rare/Never	Referent							
1-24 hours	0.98 (0.74-1.30)	1.00 (0.80-1.30)	0.90 (0.60-1.20)	0.80 (0.60-1.10)	0.70 (0.5-1.1)	1.10 (0.7-1.6)	0.70 (0.40-1.30)	0.90 (0.40-2.00)
30 minutes-1 hour	0.99 (0.69-1.41)	1.00 (0.67-1.47)	1.10 (0.73-1.66)	0.84 (0.57-1.24)	0.97 (0.64-1.49)	0.81 (0.42-1.55)	0.67 (0.34-1.32)	0.76 (0.29-1.94)
6-30 minutes	0.81 (0.59-1.13)	0.95 (0.65-1.38)	0.95 (0.66-1.36)	1.02 (0.73-1.44)	0.91 (0.58-1.42)	0.89 (0.47-1.67)	0.63 (0.32-1.24)	0.73 (0.29-1.81)
Within 5 minutes	0.85 (0.60-1.12)	1.11 (0.80-1.54)	0.87 (0.62-1.23)	1.05 (0.74-1.49)	1.44 (0.94-2.21)	1.16 (0.67-2.00)	0.49 (0.24-0.97)	2.77 (1.49-5.18)

¹ Includes little cigars and cigarillos.

² After waking.

Referent category = LC1 Cigarette Smokers (n = 2287). Significant (p < .05) adjusted odds ratios are shown in bold.

51.9% of youth cigarette smokers reported use of any non-cigarette tobacco product. In contrast, in the present analysis, 70.5% of past-month cigarette smokers reported use of at least one other tobacco product.

The shift from relatively exclusive cigarette smoking to more diverse forms of tobacco use can further be seen in analyses of the 2010–2011 Minnesota Adolescent Community Cohort (25). A LCA from this manuscript involved six items including any past-month use for cigarette smoking and any *lifetime* use for smokeless tobacco, snus, e-cigarettes, hookah, and cigarillos. The majority of participants in this survey were included in a class (“No/limited use”, 60%) characterized by low probabilities for any use. The next most prevalent class, “Cigarette smokers” (13%), was followed closely by latent classes for lifetime use of “Cigarillos/hookah” (10%) and “Snuff/snus” (10%), as well as a less prevalent class of “Poly-users” (7%). Our analysis here represents additional transition as classes with current (rather than lifetime) use of non-cigarette products emerge. This decline in the dominance of cigarette smoking among young tobacco users is likely due to multiple factors, such as increased stigmatization of cigarette smoking (36), higher taxes and regulation of cigarettes (37), and perception of reduced harm for other tobacco products (38,39).

Next to Cigarette Smokers, the next most prevalent class was Cigar Smokers. The questions used by the 2012 and 2013 NYTS do not discriminate between different types of cigars, such as cigarillos (“little cigars”). However, it is likely that youth reporting cigar use are more likely to be using little cigars, particularly brands such as Black & Milds, rather than full-size and often more expensive cigars (24,40–43). Cigarillos can be quite similar to cigarettes in terms of size and manufacturing process, but are classified as cigars based on the use of tobacco or tobacco-based wrappers. In the United States, all types of cigars are currently unregulated by the federal government, although they are included in the deeming statement (44). Due to current unregulated status and concurrent lack of federal taxes, they are allowed to be sold individually and can be much less expensive than standard cigarettes (45). This may partially explain the finding here that Black tobacco users were more likely than White tobacco users to be classified as Cigar Smokers, rather than Cigarette Smokers. Increased cigar smoking among African-Americans relative to Whites appears to be a relatively recent phenomenon, with rates among African-American youth increasing somewhat dramatically from 2011 to 2012, but remaining relatively stable for other racial groups (43). In 2014, e-cigarettes were the most commonly used tobacco product among White and Hispanic youth, but, for African-Americans, cigar use was more common (3).

Smokeless Tobacco User classification, on the other hand, was less likely among African-American children and adolescents, consistent with other research (46–48). Notably, the Smokeless Tobacco User classification included moderate probabilities for past-month cigarette, cigar, and snus use, similar to other findings indicating exclusive ST use is relatively rare (49,50). High probability of ST use, as well as cigarette and cigar smoking, was also present in the Tobacco Smokers/Chewers and Tobacco/Snus Users groups. Given that there is limited evidence of associations between ST use and tobacco-related disease risk (10), it will be important to continue to enhance our understanding of mechanisms and pathways linking smokeless tobacco usage and cigarette smoking.

In contrast to the first three classes, classes involving hookah use included a relatively lower probability of hookah use in combination with moderate and high probabilities for usage of other substances. Hookah lounges are increasingly prevalent and may increase tobacco usage due to misperceptions of reduced harm (51). This usage of tobacco and nicotine may result in dependence (52). However, hookahs provide an inconvenient form of nicotine delivery and thus adolescents may be tempted to begin to use other more convenient, portable nicotine delivery forms, such as cigarettes, cigars, pipes, and e-cigarettes. Indeed, some e-cigarettes are marketed as “e-hookahs,” (53) perhaps capitalizing on safety misperceptions and the need for more convenient forms of nicotine delivery as dependence increases. Arguably in support of the concept of hookah use acting as a gateway into other tobacco products, Tobacco/Hookah Smokers were significantly more likely to be older, whereas there was no age difference for the Hookah Smokers class, which included much lower probabilities of other tobacco product usage.

In contrast to prior research (54), we did not find gender differences among classes with high probabilities of hookah smoking. More recent research suggests similar rates of hookah use among young adult men and women (39,55). In terms of race/ethnicity, Hispanics were more likely than Whites to be both Hookah Smokers and Tobacco/Hookah Smokers, consistent with prior research in Florida (56) and New Jersey (57). The reason for this racial disparity, which has increased in recent years, is unclear and may benefit from qualitative study (56).

E-cigarette use has shown astounding growth among young tobacco users. In 2014, more youth were using e-cigarettes than cigarettes (3). In 2012 and 2013, e-cigarette use levels were more modest, although still significantly higher than previous years. Notable probabilities of e-cigarette use were present in most of the classes, suggesting increased experimentation. There was

also a small class of nearly exclusive E-cigarette Users. E-cigarette Users were less likely than Cigarette Smokers to report early morning tobacco craving, suggestive of lower levels of nicotine dependence. This is in contrast to Polytabacco Users, a class with high probabilities of reporting past-30 day use of all of the tobacco products listed, who were more likely than Cigarette Smokers to report early morning tobacco craving. Polytabacco Users were also more likely to report identifying with a racial group other than White, Asian, Black, or Hispanic.

4.1. Limitations

As a cross-sectional study, we cannot make any determinations regarding causal effects of these classes. For example, the relationship between the E-cigarette Users class and decreased rates of early morning craving may be explained by multiple factors. For example, it could be due to reduced levels of nicotine delivery in e-cigarettes, particularly those widely available in 2012 and 2013 (58,59). Alternatively, this association may instead be explained by those who are less likely to develop dependence for other reasons, such as individuals with higher socioeconomic status or greater tendency to avoid risk-taking, choosing to use e-cigarettes, a tobacco product that many believe to carry the lowest risk of harm (8). Additionally, it is unclear if the proxy measure of nicotine dependence used is appropriately modified. The measure used in the NYTS examines time from waking to first tobacco craving, rather than time to first cigarette. This seems appropriate given that this population of children and adolescents may be less likely to consume tobacco early in the morning. Indeed, reports even of tobacco craving were relatively rare. However, unlike the extensively studied and relatively well-supported measure of time to first cigarette (60,61), there is little literature on this measure of time to first tobacco craving. Although research on this measure for tobacco products other than cigarettes is limited, current findings support its use (62,63).

Despite noted limitations, there are major strengths of this study. For example, we have the advantage of a large sample size that allows for latent analysis. Further research can help examine if these classes are relatively consistent in other populations or in other time frames. Longitudinal research may help to understand if these patterns of polytabacco usage are useful in the prediction of future health problems or difficulties in quitting. Such longitudinal research is currently rare and what does exist may be less relevant for the current tobacco marketplace. For example, research on ST suggests transitions into cigarette smoking are more common among ST users than transitions out of cigarette

smoking, but this research relies primarily on data collected over a decade ago (50). Research on e-cigarettes is still in its infancy, but analyses in Los Angeles ($N = 2350$) and nationwide ($N = 694$) suggest that e-cigarette usage among young non-smokers is associated with increased risk of transitions to cigarette, cigar, and hookah smoking (64,65).

5. Conclusion

Youth cigarette smoking declined in recent years, but rates of overall youth tobacco use and polytabacco usage (use of >1 tobacco product) remained stable. Identified classes demonstrate new patterns of tobacco product usage. These new patterns in tobacco product usage are in need of continuous monitoring to better understand if reductions in youth cigarette smoking, but relatively sustained patterns of tobacco usage, ultimately result in overall improved public health.

Disclosure statement

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